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PRODUCTION AND UTILIZATION OF COKE GAS IN THE USSR

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Introduction

Gas, both natural and manufactured, has acquired tremendous importance in the USSR fuel economy. In 1940, the output of natural gas in the USSR was 1045 percent of that of 1913. At present, billions of cubic meters of natural gas are extracted and used in the country each year. The following gas pipelines were constructed and put in use in recent years Saratov--Moscow, Dashava--Kiev (natural gas), Kokhtla-Yarve--Leningrad (shale gas). At the beginning of 1954, 85 percent of the population of Moscow were making use of gas and more than 80 percent of all apartments in Leningrad now have gas service. The population of Moscow saves 170 million rubles yearly by using gas in place of firewood and kerosene, and the population of Leningrad about 80 million rubles.

Coke gas is a very important manufactured gas. At present, there are three systems of processing solid fuels by the pyrogenic method, without the introduction of air.

1. Processing at low temperatures of 450-550 degrees centigrade (semi-coking)

2. Processing at medium temperatures of 600-750 degrees centigrade (medium-temperature coking)

3. Processing at high temperatures of 900-1,000 degrees centigrade (coking). These systems differ not only in temperature factors but, in the majority of cases, in the content of the raw material being processed, the type of apparatus used, and the ultimate goal of the process.

Peat, lignite, bituminous, noncaking coals, sapropels, and bituminous shales are subjected to semicoking. The large number of designs of semi-coking ovens used for low-temperature processing corresponds to the diversity in types of fuel which can be used for semicoking. These ovens are usually divided into two groups according to the heating principle, ovens with inside heating and ovens with outside heating.

The main purpose of semicoking is to obtain primary tar (output 5-15 percent of raw material), which is used in the production of liquid fuel. The hard residue, so-called semicoke, the output of which ranges from 55-75 percent of the processed fuel, is used as a smokeless fuel, burned in boilers of electric power stations, and is subjected to complete gasification.

The output of products from semicoking of different types of fuel is given in the following table:

Output of Products of Semicoking in Percent of Dry Coal

Name of Deposit	Semicoke	Primary Tar	Gasoline From Gas	Pyrogenesis Process By-product Water	Yield of Gas (cu m/ton)
Moscow Basin	71.0-76.5	4.8-7.8	0.16-0.32	4.5-10.5	62.0-86.4
Lisichansk (Donbass)	68.4-74.3	8.3-18.1	--	3.1-10.6	51.0-82.2

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Name of Deposit	Semicoke	Primary Tar	Gasoline From Gas	Pyrogenesis Process By-product Water	Yield of Gas (cu m/ton)
Kuzbass	72.9-74.6	10.2-13.0	0.23-0.30	2.0--4.9	[illegible]
Cheremkhovo boghead	39.4	39.1	--	5.6	--
Cheremkhovo sapropels	47.8-60.9	14.8-31.[illegible]	[illegible]-0.85	7.2-18.0	--
Chelyabinsk	62.2	4.4	--	4.4	--
Gdovskiy (bituminous shale)	67.3	23.7	--	--	32.8

Caking and slightly caking bituminous coal, preferably with a high content of volatile matter, gas coal and gas-flame coal serve as raw material for medium-temperature coking. Medium coking is carried out in narrow-chamber ovens.

As a result of the process there is obtained about 75 percent of solid residue, 9-10 percent volatile matter, up to 8.5 percent tar, and about 150-200 cubic meters of gas per ton of charge. The tar contains a considerable amount of phenol. The gasoline-benzene fraction is a completely high-grade motor fuel. About 50 percent of the gas produced is used for heating ovens but the rest is used for illuminating gas.

The chief raw material for high-temperature coking is caking bituminous coal which yields in coking about 73-78 percent of coke (including 70-74 percent metallurgical coke), 15-18 percent gas, 2.5-4.5 percent tar, 0.8-1.2 percent benzene hydrocarbons, 0.25-0.4 percent ammonia, and 3-5 percent pyrogenesis process by-product water.

Influence of Length of Coking Period on Quantity and Quality of Gas

Gas changes in quantity and quality depending on the length of time which has elapsed since the start of thermal decomposition of the coal in the charge. The calorific value of the gas changes about 1,500 calories per cubic meter during the coking process (30-35 percent). The continuous decrease in methane content and heavy hydrocarbons in the gas and the corresponding increase in the hydrogen content cause a regular decrease in the specific weight of the gas, particularly intense at the end of the coking period when the hydrogen content of the gas reaches 75-85 percent.

Ten charges of coal from eastern regions with a content of volatile matter ranging from 20.7-38.8 percent were coked. The following table indicates the amount of gas released during each hour of the coking process:

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Content of Charge	Volatile Matter Content (%)	Plastometric Coordinates (mm) x	y	Hours of Coking and Amounts of Coke Gas (kg) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bukachacha gas coal	36.8	33	10	239	205	196	185	183	179	180	182	183	174	192	194	124	68	--
Suchan gas coal	32.6	26	15	235	202	189	184	183	187	136	185	186	188	196	204	193	143	101
Leninsk coal, 40%; Prokop'yevsk coking coal, 60%	27.7	32	17	209	192	185	180	177	177	177	174	174	181	168	122	85	67	--
Karaganda coal	30.4	30	14	237	217	209	202	199	197	197	195	196	211	195	153	107	--	--
Prokop'yevsk coking coal	20.7	20	12	195	183	171	160	160	161	163	161	165	181	151	114	61	--	--
Prokop'yevsk coking coal, 75%; Osinovskiy fat coal, 25%	24.0	25	15	216	205	200	188	185	183	182	178	177	182	185	156	133	--	--
Prokop'yevsk coking coal, 50%; Osinovskiy fat coal, 50%	25.9	17	21	209	195	196	186	179	176	176	178	174	177	184	173	141	75	--
Prokop'yevsk coking coal, 40%; Kizel coal, 50%; Anzherskiy coal, 10%	27.0	27	20	212	187	174	170	160	154	152	149	148	153	163	162	116	42	--
Osinovskiy fat coal	28.2	8	24	215	201	195	182	178	172	169	167	167	167	170	150	110	--	--
Kizel fat coal	38.8	--	--	235	207	194	185	176	172	165	159	156	151	134	119	87	--	--

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The data indicates that during the first 2-3 hours of coking the liberation of gas is lowered, then, for several hours, it remains almost constant. After this, an acceleration takes place followed by a sharp reduction lasting until the completion of the coking period.

The following table shows changes in the content of the gas and in the calorific value during the coking period:

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Hours of Coking	Content of Gas (% by volume)							Calorific Value (cal/cu m)
	CO_2	C_mH_n	O_2	CO	H_2	CH_4	N_2	
Experiment No 1 (Coking Period - 15 hr)								
3	4.1	4.4	0.9	4.4	53.0	29.2	4.0	4,755
6	2.8	3.1	0.9	6.0	57.0	26.6	3.6	4,462
9	2.4	2.8	0.7	6.1	59.4	25.6	3.0	4,403
12	1.8	1.9	0.8	6.4	63.6	22.5	3.0	4,089
14	0.6	0.6	0.4	5.2	75.8	14.0	3.4	3,421
Experiment No 2 (Coking Period - 15 hr)								
5	3.3	3.5	0.7	6.3	54.7	26.9	4.5	4,494
8	3.9	2.8	0.7	7.0	57.3	24.5	3.8	4,270
11	2.1	1.6	0.5	5.8	64.0	23.0	3.0	4,075
14	1.4	0.8	0.4	5.8	77.5	11.3	2.8	3,286
Experiment No 3 (Coking Period - 15 hr, 30 min)								
3 1/2	4.7	3.9	0.6	5.4	52.4	29.0	4.2	4,666
6 1/4	4.1	3.9	0.8	5.8	55.1	28.0	2.3	4,653
9 1/4	3.3	2.9	0.6	5.6	57.2	27.6	2.8	4,507
12 1/4	2.5	1.9	0.5	5.6	59.4	27.2	3.0	4,367
15	1.3	0.3	0.5	5.4	75.6	13.9	3.0	3,368
Experiment No 4 (Coking Period - 16 hr, 45 min)								
4	3.9	4.0	0.9	5.6	54.6	28.6	2.4	4,712
6	3.4	3.4	0.9	5.5	55.5	27.8	3.5	4,562
9	2.8	3.3	0.7	5.8	56.6	26.0	4.8	4,429
12	2.6	2.8	0.6	6.0	58.9	25.3	3.8	4,350
15	0.9	0.9	0.5	4.9	71.6	15.4	5.8	3,474

Because the gases obtained during the different hours of the coking period differ so much in content and quantity, it is necessary to mix these gases in order to standardize them and in this way to create an even load on the chemical apparatus of the condensation and recovery shops. This mixing process takes place in gas collectors and the gas drawn off from these collectors is a standardized mixture of the gases and vapors obtained during the course of the entire process of coking coal.

Such gas contains as a rule (in percent by volume): CO_2 -- 2-4 percent, C_mH_n (ethylene, propylene, etc.) -- 2-4 percent, CO -- 6-8 percent, O_2 -- 0.4-0.8 percent, H_2 -- 55-60 percent, CH_4 -- 24-28 percent, and N_2 -- 3-7 percent.

In addition to this, the coke gas contains the following (grams per cubic meter): tar (a considerable amount of which is condensed in the gas collector) -- 100-120, benzene hydrocarbons -- 30-40, ammonia -- 7-10, hydrogen sulfide -- 5-20, cyanogen -- 0.1-1, nitric oxide, carbonbisulfide, etc. -- small amounts.

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This complex and valuable mixture of gases and vapors is subjected to special processing to extract from it valuable chemical products and to prepare the gas for further utilization.

Coal Storage Before Coking Scarcely Affects Quantity and Quality of Coke Gas

Coking of coal which has been stored for a long time, and has naturally become somewhat oxidized, results in a yield in coke gas which does not differ materially from the output from the original coal as can be seen from data in the following table:

Type of Coal	Storage Period, Days	Actual Yield of Gas, (cu m per ton)
Osinovskiy Zh 1	Before storage	317
	150	319
	190	319
Karaganda uncleaned coal	Before storage	286
	50	282
Mine imeni Molotov, K 1	Before storage	290
	45	293
	95	292
	200	285

The content of the gas is also only slightly changed as shown in the following table, although there is a small increase in the carbon dioxide and carbon monoxide content:

Type of Coal	Storage Period, Days	Contents of Coke Gas (% by volume)						
		CO_2	H_2S	C_mH_n	CO	H_2	CH_4	N_2
Karaganda uncleaned	Before storage	2.15	0.8	3.48	8.02	53.71	29.0	2.14
	35	2.18	0.74	3.75	7.23	56.10	27.45	2.55
	50	2.23	0.70	3.65	8.28	56.1	27.55	1.46
Mine imeni Molotov, K 1	Before storage	1.72	0.15	2.60	4.86	62.13	27.8	0.84
	45	1.75	0.15	2.63	4.89	59.67	29.31	1.6
	95	1.80	0.15	2.60	5.00	59.32	30.0	1.13
	200	1.90	0.17	2.58	5.00	60.35	30.0	--

Relation Between Different Elements in Coking Charge and in Coke Gas

Data obtained from studies on the distribution of elements entering into the composition of coking coal vary somewhat because of the influence of the temperature of coking on the character of the distribution of these elements. The following table gives average data obtained in coking a charge of Donets coal (with a volatile matter content of 26.9 percent) in Dinas brick coke ovens for 14.1 hours with the temperature at the heating walls 1,347 degrees centigrade on the coke side and 1,319 degrees centigrade on the pusher side:

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Distribution of Elements (% by wt)

	C	H	N	O	S
Charge	100.00	100.00	100.00	100.00	100.00
Coke	85.91	6.86	45.00	4.5	60.60
Gas	9.25	63.83	40.19	33.26	--
Tar	3.28	8.86	4.41	1.11	15.55
Benzene	1.45	1.90	--	--	--
Pyrogenesis process by-product water	--	13.04	--	61.00	--
Ammonia	--	1.09	10.40	--	--
Hydrogen sulfide	--	0.54	--	--	23.81
Inconsistencies of balance	0.11	3.28	--	0.13	0.04

The nitrogen content of Donbass coal ranges between very narrow limits (1.4-1.7 percent). Since 20-40 percent of this amount passes over into the coke gas, 2.8-6.8 kilograms of nitrogen, or 2.2-5.5 cubic meters, go into the gas from one ton of coking coal. Inasmuch as the average yield of gas amounts to 300 cubic meters per ton, the theoretical nitrogen content of the gas should range from 1.0-2.5 percent. Even if 50 percent of the nitrogen in the coal passes over into the gas, and the maximum nitrogen content of the coal is taken at 2 percent, the theoretical nitrogen content of the coke gas should not exceed 3 percent.

The sulfur content of coal varies considerably, not only for different basins and deposits, but for seams and mines. In the Donbass the sulfur content of coal averages 2-3 percent, in the Kuzbass, 0.5-0.7 percent, in Karaganda, 0.8-1.1 percent. Pyrite and organic sulfur may make up from 10-20 to 60-70 percent of the total sulfur content of the coal.

The content of hydrogen sulfide in coke gas is determined on the basis of the sulfur content of the original coal. In coke gas of southern plants, that is, gas obtained by coking Donbass coals, the hydrogen sulfide content amounts to 15-20 grams per cubic meter. In gas from Kuzbass and Karaganda coals it is considerably less.

As the moisture content of coal increases, the yield of coke decreases, since water gas if formed at the expense of the carbon in the coke. Therefore, the yield of gas up to a specific point is increased with the increase of the moisture content of the coal. Data obtained under laboratory conditions showed that an increase in the moisture content of coking coal from 0.71 to 8 and 16 percent [sic] increased the yield of gas from 311 cubic meters per ton to 318 cubic meters.

Data on Coke Gas From Coals of Various USSR Coal Regions

In 1937-1938, the Khar'kov Coal Chemical Institute made a study of the yield of gas and chemical products from the majority of coals of the Donbass that were used for coking. Coking was conducted in laboratory ovens with a small batch of coal. The following table records results of these tests:

Coal	Volatile Matter Content (%)	Yield of Gas From Organic Mass of Coal* (% by wt)	Yield of Gas From Organic Mass of Coal* (cu m per ton)	Content of Gas (% by vol) CO_2	C_mH_n	CO	H_2	CH_4	N_2	Specific Weight of Gas	Calorific Value (per cu m)
Mine No 3, type G	40.34	15.15	247	3.7	4.2	8.3	48.7	32.8	2.3	0.533	4,881
Mine No 5/6 imeni Dimitrov, type G	37.03	16.15	342	4.5	3.0	10.9	52.9	27.6	1.1	0.523	4,439
Charge made up of type G (11 %), PZh (45%), K (27.5%), and PS (16.5%)	30.18	12.1	297	1.8	2.2	4.9	55.7	32.1	3.3	0.446	4,665
Charge made up of type PZh (60%), K (20%), and PS (20%)	29.41	15.5	346	2.3	2.2	3.8	62.1	27.1	2.5	0.446	4,413
Charge made up of G (10%), PZh (50%), K (25%), and PS (15%)	28.31	14.45	376	2.2	2.8	4.9	56.7	31.0	2.5	0.443	4,623
Mine No 13-bis, type P[illegible]	28.07	15.2	346	2.6	2.3	7.4	63.6	21.6	2.5	0.421	4,112
Mine No 60, type K	25.87	13.5	318	4.6	1.0	5.0	61.1	26.7	1.6	0.432	4,107
Mine 21 V, type K	25.63	13.2	313	2.4	1.8	4.8	64.1	24.4	2.5	0.398	4,201
Mine No 12, type PS	15.05	8.6	272	1.7	1.2	2.6	68.1	26.4	-	0.332	4,216

*On the basis of 4,000 calories per cubic meter.

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Experiments indicate that Kuzbass coals may be divided into five groups from the standpoint of their gas yield:

1. Gas coals (Leninsk and others) with a volatile matter content of 40 percent and an output of gas (on the basis of 4,000 calories per cubic meter) averaging 374 cubic meters per ton.

2. Fat coals (Osinovskiy, Novo-Osonovskiy, and other deposits) with a volatile matter content of 28-35 percent and an average gas yield of 311 cubic meters per ton.

3. Coking-fat and coking coals (Prokop'yevsk deposit) with a volatile matter content of 21-26 percent and an average gas yield of 308 cubic meters per ton.

4. Coking coals (Anzhero-Sudzhensk, Kiselevsk and other deposits) with a volatile matter content of 17-19 percent and an average gas yield of 289 meters per ton.

5. Coking coals, lean coals, lean caking coals (Prokop'yevsk, Anzhero-Sudzhensk and other deposits) with a volatile matter content of 14-18 percent and an average gas yield of 275 cubic meters per ton.

Experiments with Kuzbass coals (Baydayevskiy, Chertinskiy and others) indicate that the gas yield from coking them under laboratory conditions is 370-390 cubic meters per ton.

For Karaganda coals (KZh, K, KO) the yield of gas is about 290-310 cubic meters per ton and an increase in the gas yield is noted with an increase in the volatile matter content.

Kizel basin coals yield a high output of gas during coking and the relation of the volatile matter content of these coals to the gas yield is expressed as follows:

Volatile Matter Content (%)	Gas Yield in Cubic Meters per Ton (on basis of 4,000 cal per cu m)
36.8-40	330
40-41	338
41-43	352
43-44	359
44-46	353 [sic]
46-49	365

The gas yield from Pechora basin coal is 305-330 cubic meters per ton and is directly related to the volatile matter content of the coal which ranges from 31-35 percent.

Preliminary tests indicate that coals of Central Asia are close to the Osinovskiy deposit in the Kuzbass as regards their yield of coke gas.

An increase of the amount of gas coal in the charge leads to an increase in the yield of coke gas even if the amount of volatile matter is not increased. In coking a number of experimental charges of Donbass coals with a gas coal content up to 40-70 percent, the gas yield was 340-380 cubic meters per ton with a methane content of 26-30 percent. Experimental coking of gas coal from the Krasnoarmeyskugol' deposit in the Donbass under industrial conditions showed that it was possible to obtain 360 cubic meters of gas, with the following content, per ton of coal: 3.6 percent CO_2, 4.1 percent C_mH_n, 0.5 percent O_2, 5.1 percent CO, 34.2 percent CH_4, 49 percent H_2, 3.5 percent N_2. The calorific value of this gas was 4897 calories per cubic meter.

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Industrial experimental coking of Lisichansk coal in a change made up of 70 percent long-flame coal and 30 percent of a PZh concentrate from the Novo-Uzlovskiy TsOF (Central Coal-Cleaning Plant) and with a volatile matter content of 39.2 percent yielded 369 cubic meters of gas per ton (based on 4,000 calories per cubic meter).

A high yield of gas (339-359 cubic meters per ton) was also obtained from experimental industrial coking of a charge made up of 50 percent Tkvarcheli coal and 50 percent Tkibuli coal with 37.5 percent volatile matter. The gas contained 26.6 percent of methane and had a calorific value of about 4,400 calories per cubic meter.

Coke Ovens in Use in the USSR

Both chamotte brick and Dinas brick can be used in constructing coke ovens but in the USSR only Dinas brick ovens are being constructed and what chamotte brick ovens are in use there have very little significance. The reasons for this are as follows: The softening point of Dinas brick is at a considerably higher temperature than in the case of chamotte brick. This makes it possible to maintain a temperature up to 1,400-1,450 degrees in the heating walls of Dinas brick coke ovens as against 1,230 degrees in chamotte brick ovens. The higher temperature in the Dinas brick ovens as well as the relatively great heat conductivity of the Dinas brick, makes it possible to reduce the length of the coking period in these ovens as compared with chamotte brick ovens.

The height of the coking chamber in modern Dinas brick ovens is usually about 4,300 millimeters. The chambers are loaded with the coal charge in such a way that the distance from the top of the coal charge to the arch of the chamber is 200-300 millimeters. Consequently, the useful height of the chamber is 4,000-4,100 millimeters. The total length of the heating wall, consisting of 26-28 heating flues, is 13.1 meters, the useful length, 12.3 meters. The width of the coking chamber is unequal along the length of the oven. To facilitate the transmission of coke, the chamber is made 40-60 millimeters wider on the coke side than on the pusher side. As an average, the width of the coking chamber amounts to 407 millimeters, although there are chambers 450 millimeters or more wide. The heating wall is wider on the pusher side (760-770 millimeters) than on the coke side (710-730 millimeters). The thickness of the walls of coking chambers usually ranges, depending on the design of the coke ovens, from 105-127 millimeters.

The useful volume of coking chambers amounts accordingly to about 20 cubic meters and the content of a single wet charge is 16.0-16.5 tons (about 15 tons of dry charge).

Coke ovens are blocked in batteries consisting of 45-69 ovens, although there are batteries containing fewer ovens.

To produce small amounts of coke gas, it is possible to use simple, very effective vertical chamber coke ovens, constructed in one of the USSR gas plants. Each block consists of five coking chambers, lined with Dinas brick, having six heating walls, two recuperators, and one gas generator.

The coking chamber has an average width of about 300 millimeters, and a useful volume of 2.2 cubic meters. The volume of a single charge is 1.5-1.6 tons. The gas generator works on coke the consumption of which amounts to about 20 percent. The coking period in these ovens lasts about 12 hours. To increase the yield of the gas after the completion of coking, superheated steam is fed from below into the chambers for 4-5 hours. The total yield of gas is 400-420 cubic meters per ton of the charge (on the basis of gas with a calorific value of 4000 calories per cubic meter).

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The simplicity of the design and servicing of vertical chamber ovens, the high yield of gas, and the possibility of using coals with low caking properties, make it expedient to construct such ovens in small coke-gas plants.

Increased Temperature at End of Coking Period Increases Gas Yield

It has been established that an increase in the temperature of the coke being issued from the oven from 920-925 degrees to 1,000-1,040 degrees results in an increase in the output of coke gas (based on 4,000 calories per cubic meter) from 320-325 to 330-335 cubic meters per ton with a simultaneous increase in the hydrogen content and a decrease in the methane content of the gas.

Experiments indicate that an increase in the temperature in the heating system and of the temperature of the coke produced, that is, of the total temperature potential of coking, with no change in the length of the coking period, brings about an increase in the output of gas, an increase in the hydrogen content of the gas, and a decrease in the methane content, in the indeterminate hydrocarbons, and the calorific value of the gas. If the temperature at the end of coking is raised 80-100 degrees, the gas yield will be increased 4-6 percent.

Data on these experiments are given in the following table:

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Number of Experiment	Coking Time Hours	Temperature of Produced Coke	Output of Gas (on basis of 4,000 calories per cu m per ton)	Content of Gas (% by volume) CO_2	C_mH_n	O_2	CO	CH_4	H_2	N_2	Specific Weight of Gas (kg per cu m)	Calorific Value of Gas (cal per cu m)
Charge No 1 (G - 20%, PZh - 45%, K - 20%, PS - 15%)												
1	16	940	295	1.7	2.4	0.9	6.1	25.4	59.3	4.2	0.445	4,244
		1,037	310	1.9	2.1	-	6.3	24.6	61.2	4.9	0.425	4,210
2	15	938	300	1.8	2.3	0.6	5.9	24.8	59.8	4.8	0.440	4,242
		1,008	312	1.7	2.3	0.8	6.2	24.4	60.9	3.7	0.430	4,226
Charge No 2 (G - 30%, PZh - 30%, K - 20%, PS - 20%)												
3	15	829	295	1.8	2.5	0.5	5.4	25.8	59.3	4.7	0.440	4,334
		941	303	1.9	2.15	0.6	6.2	24.35	59.9	4.9	0.440	4,190
		1,028	322	1.7	2.1	0.8	6.1	23.9	60.4	5.2	0.430	4,149
4	16	948	314	-	2.20	-	-	24.9	60.8	-	0.430	4,248
		1,011	323	-	2.04	-	-	24.6	61.7	-	0.419	4,223

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Special Methods for Increasing the Gas Yield

Two methods of increasing the output of gas from coke ovens are the feeding of water vapor into the coking chambers and coking of mixtures of coal and oil.

In one plant, water vapor (at a pressure of 5 atmospheres) was introduced into the chamber through the lower part of the door from the coke side, in the amount of 120 kilograms per hour per oven. The steam was fed for 6 hours after gas had stopped being liberated from the charge. The yield of water gas was 100-120 cubic meters per hour and the consumption of steam for the production of the gas was 1.1-1.2 kilograms per cubic meter. The percent of utilization of the water vapor for the production of the gas was about 45-55, and the content of the gas obtained was approximately as follows: CO_2, 8-9 percent; O_2, 0.2 percent; CO, 35-36 percent; CH_4, 1.2-1.4 percent; H_2, 48-50 percent; N_2, 5-6 percent. The calorific value of the gas was 2650-2750 calories per cubic meter.

According to available data, the mechanical toughness of the coke is notably decreased by the introduction of steam into the coking chamber. Therefore, this method can be used only in gas plants, that is, plants which produce nonmetallurgical coke.

Since the coking period is lengthened by the time that the steam is being introduced, the productivity of the plant for coke is considerably reduced and the hourly output of gas is also reduced 2-3 percent. The introduction of steam into the coking chambers also causes some cooling of the chamber walls.

To increase the effectiveness of the use of steam in this connection, a method was worked out whereby superheated water vapor was blown into the area beneath the crown of the oven from the coke side with the hydraulic valve of the stack closed. Entering the chamber in a diagonal direction, the steam goes out at the floor of the oven on the pusher side, is conveyed by a special connecting pipe to the second oven and, passing through this also in a diagonal direction, it goes out to the stack and the gas collector. The coefficient of decomposition of the steam in such consecutive passage through two chambers is about 90 percent. About 0.5 kilogram of steam is consumed in the production of one cubic meter of water gas with a calorific value of 2,600-2,800 calories. At the end of the coking period the steam is fed in for 7 hours at the rate of 150-160 kilograms per hour. Reduction of the productivity of the ovens for coke is evident in this method since the coking period is extended 7 hours.

Coking of mixtures of coal and oil is being carried out to increase the output of aromatic hydrocarbons and gas. V. D. Frishberg reports the following results from coking a coal-mazut mixture (additive to charge - 5.5 percent mazut): The yield of gas rose from 307 to 351 cubic meters. The C_mH_n -content of the gas increased from 1.88 to 2.76 percent and the CH_4 -content rose from 19.9 to 24.5 percent. There was also a rise of almost 300 calories in the calorific value of the gas (from 3,942 to 4,223 calories per cubic meter). At the same time, the hydrogen content of the gas dropped from 60.6 to 56.2 percent.

Utilization of Coke Gas as Fuel

Coke gas is one of the best gaseous fuels because of its high calorific value (4,000-4,400 calories per cubic meter of 8,500-9,500 calories per kilogram), the temperature of combustion, the small amount of inert constituents, the relatively high content of CO_2 and H_2O in the products of combustion. For these reasons it is widely used in various fuel-consuming

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aggregates. The chief consumers of coke gas and also mixtures of it with lean gases (blast-furnace, generator) as fuel are the following:

1. Coke ovens

2. Open-hearth furnaces

3. Soaking pits and rolling-mill installations (blooming-mill pits, etc.)

4. Furnaces in glass, ceramic, chemical plants, etc., various types of driers

5. Gas motors and automobile motors (compressed gas)

6. Household requirements (gas stoves, gas heating, gas refrigerators, etc.)

Coke gas is also used for fueling and firing of steam engines, for cutting metal, etc.

The most important consumer of coke gas is ferrous metallurgy, and the majority of important coke by-products plants of the USSR are located in the direct vicinity of metallurgical plants.

For plants with the full metallurgical cycle, the following distribution of coke gas is characteristic: open-hearth furnaces 50-60 percent, rolling mill - 20-30 percent, agglomeration plant 1-2 percent, other shops - 2-5 percent, buffer consumers (steam boilers) - 3-4 percent.

Thus, the chief consumer of coke gas in a metallurgical plant is the open-hearth furnace shop. To use coke gas in open-hearth furnaces, it is necessary to reduce its sulfur content to 2-4 grams per cubic meter.

Compressed coke gas, like other high-calorie fuel gases, is widely used in motor-vehicle engines as a substitute for liquid fuels. The use of compressed gas has the following advantages:

1. The antiknock properties of the gas tend to increase the compression ratio of the engine, boost its capacity, and reduce fuel consumption.

2. In a gas engine there is neither condensation of fuel nor dilution of lubricants which cause corrosion of the cylinders and other difficulties.

3. The process of forming a working mixture of gas and air is carried out more completely than in the case of liquid fuel.

4. An engine working on gas starts in any temperature without difficulties.

The chief disadvantages of motor-vehicle gas cylinders are:

1. Losses of useful load capacity of the machine because of the considerable dead weight of the cylinders. Different machines, while operating on coke gas, lose the following amounts of their useful load capacity: GAZ-AA, 23 percent; ZIS, 15 percent; and YaG-4, 11 percent.

2. Relatively limited radius of activity of the machines away from the gas distributing station. The road supply of the GAZ-AA machine (six cylinders) is enough for 150 kilometers, that of the ZIS-5 (eight cylinders) suffices for 100-120 kilometers.

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To convert motor vehicle transport to compressed gas, it is necessary to build gas-filling stations and this would require a suitable capital outlay. There were some gas-filling stations for coke gas and dehydrogenated coke gas in the USSR already in 1939.

In one of the USSR metallurgical combines, the fueling and firing of steam engines with coke gas instead of firewood has been carried out successfully for a number of years. There are very good prospects for a wider use of coke gas for railroad transport, particularly for intraplant transport.

Coke gas is also used for cutting metals.

Distribution of Coke Gas

The production of coke gas in the USSR, when converted to a suitable equivalent, amounts to about 50 percent of the output of electric power. One modern four-battery coke by-products plant produces in a year about 700 million cubic meters of coke gas, that is, 2.8 million megacalories which is equal to 400,000 tons of standard fuel. The distribution of this enormous amount of energy is being improved each year.

The consumption of coke gas for the plants' own requirements (heating of coke ovens, etc.) had decreased in 1940 over 1933, but the distribution of coke gas to outside customers was seven times as great and, in 1950, it was 11.4 times as great.

A certain increase in the requirements for coke gas for the plants' own use in 1945-1947 is explained by the introduction, after the restoration of the Donbass and Dnepr area, of a number of coke batteries of chamotte brick ovens and Dinas brick ovens which for technical reasons could not be converted to heating by blast-furnace gas.

For certain areas of the country, the effectiveness in the distribution of coke gas exceeded cited average figures. Thus, even before the war, in 1939, the consumption of gas for heating coke ovens amounted to 36.7 percent for the Dnepr group of plants, with about 60 percent going to outsiders. In plants of the eastern regions of the USSR, 29.8 percent of the produced coke gas was consumed in 1940 for heating coke ovens and 66.7 percent was delivered to outsiders, including 51.3 percent for metallurgy. In 1950, the consumption of coke gas for heating coke ovens was reduced in these plants to 23.6 percent and the distribution to outsiders rose to 74.6 percent, including 56.9 percent for metallurgy. Therefore, the greatest amount of coke gas distributed to outsiders is consumed for requirements of metallurgy (1940, 80 percent; 1950, 82 percent).

The following table indicates the distribution of coke gas for a number of years in percent of total amount produced:

Distribution	Years													
	28	33	36	37	38	39	40	43	44	45	46	47	48	50
Heating coke ovens	60.0	61.2	59.4	46.1	41.5	42.0	40.2	22.2	29.2	30.0	31.3	31.1	30.6	28.8
Under boilers, etc.	23.0	9.9	4.0	4.7	4.2	4.0	3.2	1.4	1.1	1.8	2.1	3.1	2.4	2.1
Total for own use of coke plants	83.0	72.1	63.4	50.8	45.7	46.0	43.4	23.6	30.3	31.8	33.4	34.2	33.0	30.9

Distribution	Years													
	28	33	36	37	38	39	40	43	44	45	46	47	48	50
Distributed to outsiders	6.3	21.0	33.2	45.9	52.9	52.5	54.6	73.8	66.2	65.2	63.9	63.6	65.4	67.1
Including metallurgy	5.9	14.9	29.8	39.2	43.3	40.9	44.2	51.3	47.4	48.3	49.8	48.4	50.9	55.1
Other enterprises	0.4	6.1	3.4	6.7	9.6	11.6	10.4	22.5	18.8	16.9	14.1	15.2	14.5	12.0
Losses and unutilized coke gas	10.7	6.9	3.4	3.3	1.4	1.5	2.0	2.6	3.5	3.0	2.7	2.2	1.6	2.0

The specific importance of blast-furnace gas, generator gas, and rich (dehydrogenated) gas in the total consumption of fuel for heating coke ovens is increasing each year: 1935, 3.9 percent; 1936, 13.8 percent; 1937, 21.4 percent; 1939, 28.1 percent; 1940, 29.3 percent; 1938, 45.6 percent.

When the coke ovens are located at a distance from sources of blast-furnace gas, it is expedient to use generator gas for heating them and to deliver the coke gas to other consumers. The use of generator gas instead of coke gas for heating coke ovens leads to an increase of 5-6 percent in the consumption of heat for coking but it increases the uniformity of heating the coking chambers along their height. The use of generator gas for heating coke ovens has been completely mastered in the USSR.

Generator-gas stations at coke by-products plants can operate on rejected coke fines and coke breeze which are tailings of the production. The use of this type of fuel requires only the simplest technological method of gasification, and the least capital and exploitational outlay. Production costs of generator gas obtained in high-capacity generators are only two thirds as great as the output price of coke gas for industrial and household purposes. This difference in production costs would take care of the expense of producing generator gas. Therefore, a number of coke-gas plants use generator gas, supplied by special generator stations, for heating coke ovens and furnish their output of coke gas to communal-domestic consumers.

In recent years, the use of coke gas for communal needs has increased considerably: in Khar'kov the consumption of coke gas has doubled and its use has increased notably in Stalino and Zhdanov. In Moscow, too, coke gas has acquired real importance in the gas balance of the city. Here it is mixed with natural gas for illumination purposes. In leningrad it is mixed with generator gas. Moscow exceeds the largest cities of Europe and the US in the consumption of gas per person.

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